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OFFROAD Modeling Change Technical Memo

SUBJECT: Changes to the Locomotive Inventory

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Summary

In 1992, staff used results from the Booz-Allen Hamilton's (BAH) study (Locomotive Emission Study) to establish the baseline locomotive inventory. The basic methodology is presented in Appendix A. In 2003, staff began updating the emissions inventory by revising the growth assumptions. These revised growth factors were incorporated into the emissions inventory used in the Air Resources Board's (ARB) 2003 Almanac on Air Quality and Emissions. With additional data, staff is now proposing further updates to the locomotive inventory to incorporate fuel correction factors and to add passenger train and Class III locomotive data. This technical memo documents the changes on growth rates made for the 2003 Almanac, as well as recent changes. Table 1 presents a summary of the emission changes from both sets of changes.

Table 1. Impact of Changes on Statewide Locomotive Inventory

	Pre 2003 ARB Almanac Inventory (tons/day)			2003 ARB Almanac Inventory (tons/day)			Difference (tons/day)		
Year	HC	NOx	PM	HC	NOx	PM	HC	NOx	PM
1987	7.2	158.8	3.6	7.2	158.8	3.6	0.0	0.0	0.0
2000	7.2	144.8	2.8	8.5	215.2	4.9	1.3	70.4	2.1
2010	7.2	77.8	2.8	8.1	130.0	4.7	0.9	52.2	1.9
2020	7.2	77.8	2.8	8.1	132.7	4.6	0.9	54.9	1.8

	2003 ARB Almanac Inventory (tons/day)			Revised Inventory (tons/day)			Difference (tons/day)		
Year	HC	NOx	PM	HC	NOx	PM	HC	NOx	PM
1987	7.2	158.8	3.6	7.2	158.8	3.6	0.0	0.0	0.0
2000	8.5	215.2	4.9	9.6	199.9	4.6	1.1	-15.3	-0.3
2010	8.1	130.0	4.7	9.8	116.4	4.3	1.7	-13.6	-0.4
2020	8.1	132.7	4.6	10.5	138.6	4.5	2.4	5.9	-0.1

Reasons For Change

During the 2003 South Coast Air Quality Management District (South Coast AQMD) State Implementation Plan (SIP) development process, industry consultants approached ARB staff to refine the locomotive emissions inventory. Specifically, their concerns were related to the growth factors and fuel correction factors used in the inventory calculations. This document outlines how the locomotive emissions inventory was updated and the subsequent changes made to address industry's concerns.

Background : Baseline 1987 Locomotive Emissions Inventory (BAH report)

Locomotive operations can be characterized by the type of service performed. For emission inventory purposes, locomotives are classified into five different service types as defined in BAH's report.

Line-haul/intermodal – Intermodal locomotives generally operate at higher speeds and with higher power than other types and incorporate modern, high-speed engines.

Mixed/bulk – Mixed locomotives are the most common and operate with a wide range of power. They also perform line-haul duties.

Local/Short Haul – Local locomotives perform services that are a mixture of mixed freight and yard service. They operate with lower power and use older engines.

Yard/Switcher – Yard operations are used in switching locomotives and are characterized by stop and start type movements. They operate with smaller engines and have the oldest locomotive engines.

Passenger – Passenger locomotives are generally high speed line haul type operations.

Categories of railroads are further explained by a precise revenue-based definition found in the regulations of the Surface Transportation Board (STB). Rail carriers are grouped into three classes for the purposes of accounting and reporting:

Class I –Carriers with annual operating revenues of $250 million or more;

Class II – Carriers with annual operating revenues of less than $250 million but in excess of $20 million; and

Class III – Carriers with annual operating revenues of less than $20 million or less, and all switching companies regardless of operating revenues.

The threshold figures are adjusted annually for inflation using the base year of 1991.

The 1987 locomotive inventory as shown in Table 2 is taken from the BAH report prepared for the ARB entitled “Locomotive Emission Study.” The study was completed in 1992 (http://www.arb.ca.gov/app/library/libcc.php). Information was gathered from many sources including ARB, the South Coast AQMD, the California Energy Commission, the Association of American Railroads (AAR), locomotive and large engine manufacturers, and Southwest Research Institute. Railroad companies, such as Southern Pacific, Union Pacific, and Atchison, Topeka and Santa Fe (ATSF), provided emission factors, train operation data, and throttle position profiles for trains operating in their respective territories. Southwest Research Institute provided emission test data.

Table 2. 1987 Locomotive Inventory in Tons Per Day, Statewide, BAH report

TYPE	HC	CO	NOX	PM	SOX
Line-Haul/Intermodal	3.97	12.89	86.21	1.97	6.36
Short-Haul/Local	0.96	3.06	21.30	0.46	1.59
Mixed	1.51	4.85	37.34	0.81	2.76
Passenger	0.10	0.22	3.24	0.07	0.30
Yard/Switcher	0.62	1.57	10.69	0.24	0.58
Total	7.16	22.59	158.78	3.55	11.59

The assumed average fuel sulfur content is 2700 parts per million (ppm) obtained from the BAH report.

Current Growth Estimates

Prior to the 2003 South Coast AQMD SIP update, growth factors were based on employment data in the railroad industry. Staff believes that the use of historic employment data, which translates to a decline in emissions in future years, may be masking actual positive growth in locomotive operations. It may be assumed that the number of employees is declining due to increased efficiency.

Changes to the Locomotive Inventory

Summary of Growth in Emissions Based on the BAH Report

Growth is estimated based on train operation type and by several operating characteristics.

> Increased Rail Lube and Aerodynamics – this arises from reduction in friction and will help reduce power requirements.

Introduction of New Locomotives – older locomotive units will be replaced by newer models.

Changes in Traffic Level – the increase or decrease in railroad activity

In the BAH report, projected emission estimates for years 2000 and 2010 were based on the factors shown in Tables 3 and 4. A substantial part of the locomotive emission inventory forecast is based upon projections of rail traffic levels. BAH projected future rail traffic level as a function of population and economic growth in the state. BAH also projected growth in emission only to 2010.

Table 3. Changes in Emissions from 1987-2000 (Exhibit 4 p. 11 of the 8/92 Locomotive Emission Study Supplement) (1987 Base Year)

Train Operation Type	Increased Rail Lube and Aerodynamics	Introduction of New Locomotive	Changes in Traffic Levels	Cumulative Net Growth in Emissions
Intermodal	-7.0%	-8.0%	17.0%	2.0%
Mixed & Bulk	-7.0%	-8.0%	2.0%	-13.0%
Local	-3.0%	-3.0%	-2.0%	-8.0%
Yard	0.0%	-1.0%	-25.0%	-26.0%
Passenger	-7.0%	-8.0%	10.0%	-5.0%

Table 4. Changes in Emissions from 2001-2010 (Exhibit 4 p. 11 of the 8/92 Locomotive Emission Study Supplement) (2000 Base Year)

Train Operation Type	Increased Rail Lube and Aerodynamics	Improved Dispatching and Train Control	Introduction of New Locomotive	Changes in Traffic Levels	Cumulative Net Growth in Emissions
Intermodal	-2.0%	-3.0%	-8.0%	25.0%	12.0%
Mixed & Bulk	-2.0%	-3.0%	-8.0%	0.0%	-13.0%
Local	-1.0%	0.0%	-12.0%	-10.0%	-23.0%
Yard	0.0%	0.0%	-10.0%	-15.0%	-25.0%
Passenger	-2.0%	-3.0%	-8.0%	15.0%	2.0%

BAH added “Improved Dispatching and Train Control” to differentiate these impacts from the “Increased Rail Lubing” which helps to improve fuel efficiency from locomotive engines. Since train control techniques are emerging from the signal company research work, these assumed changes will not impact emission until year 2000.

Based on industry's input, staff recommends several changes to the locomotive emissions inventory. These include modifying growth factors, making adjustments to control factors reflecting the U. S. EPA regulations that went into effect in year 2000, incorporating fuel correction factors, adding smaller class III railroad and industrial locomotives, and updating passenger data.

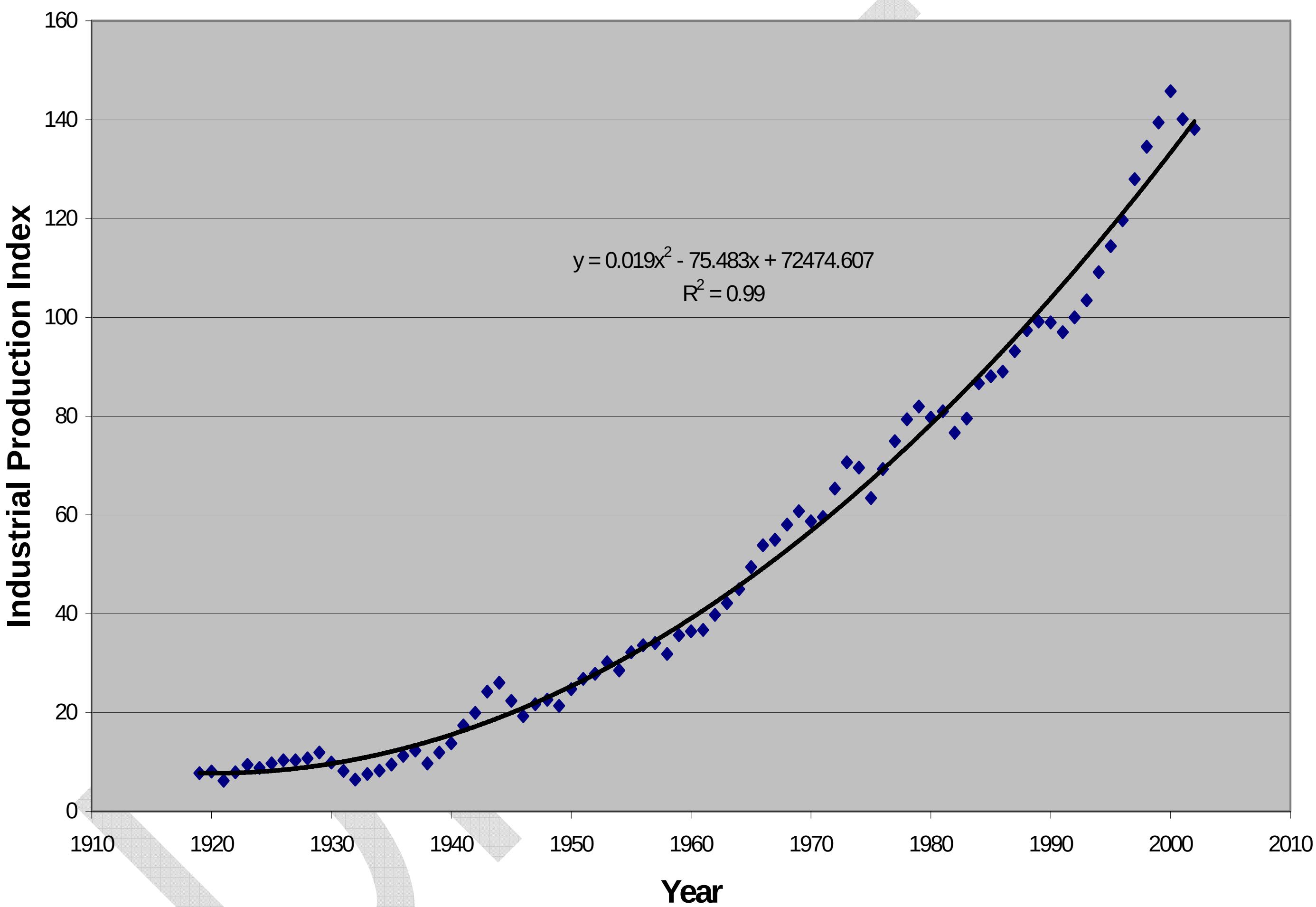
Revised Growth in Emissions (Effect of Goods Movement Plan adopted in 2006)

Staff revised the growth factors for locomotives based on new data that better reflect locomotive operations. This includes U.S. industrial production and various railroad statistics available from the AAR. Staff also reflected the effects of the goods movement from the ports of California on locomotive traffic levels. In effect, the line-haul service operation was divided into an international/foreign and a domestic influenced line haul section. Staff assumed that goods movement from the ports will affect the traffic growth level of the international portion and the regional/domestic goods movement will affect the domestic line-haul operations. Staff also assumed that the domestic line haul operation and the mixed/bulk type operation will have the same growth rates.

In calculating the international portion of the line-haul traffic growth, growth in cargo container volume was used to reflect growth in traffic level (more info on the goods movement can be found here http://www.arb.ca.gov/planning/gmerp/gmerp.htm). These growth estimates are based upon the change in number and capacity of container ships that occurred in the years 1997-2003. Specifically, the change in total installed power of container ships was used to estimate growth. Total installed power is a function of the number and the total size of container ships visiting California between 1997 and 2003. These growth rates agree well with container forecasts projected for the Ports of Los Angeles for the No Net Increase Report, Long Beach, and Oakland. Installed power growth is expected to increase approximately 5.9% annually. Staff assumed that the international portion of the line-haul traffic growth will approximate this rate.

Based on historic data recently obtained from U.S. industrial productions and the AAR, the changes in traffic levels for domestic line haul/mixed service operation were revised. Industrial production data is considered to be a surrogate for changes in traffic levels of the domestic line-haul locomotive. It is assumed that railroad activity would increase in order to accommodate the need to move more product. Industrial production is the total output of U.S. factories and mines, and is a key economic indicator released monthly by the Federal Reserve Board. U.S. industrial production historical data from 1920 to 2002 was obtained and analyzed from government sources. Figure 1 shows the historical industrial production trend (Source : http://www.research.stlouisfed.org/fred2/series/INDPRO/3/Max). Statistical analysis was used to derive a polynomial equation to fit the data.

Figure 1. Long-term Industrial Production



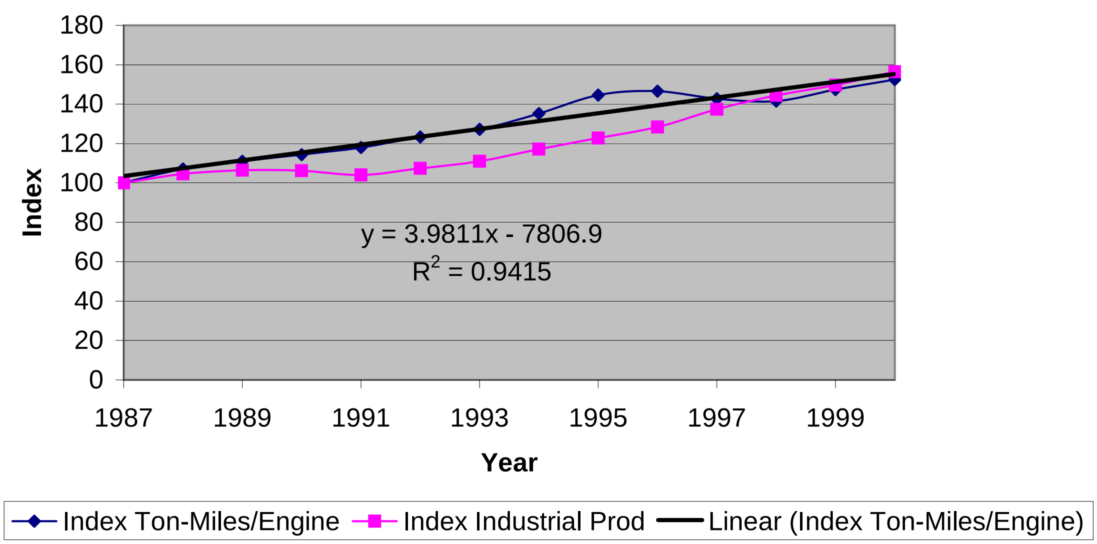
Another surrogate for growth is net ton-miles per engine. Consequently, staff analyzed railroad data from the AAR's Railroad Facts booklet (2001 edition). The booklet contains line-haul railroad statistics including financial status, operation and employment data, and usage profiles. Revenue ton-mile and locomotives in service data from the booklet were used to compute the net ton-miles per engine as shown in Table 5.

Table 5. Revenue Ton-Miles and Ton-Miles/Engine (AAR Railroad Facts 2001 edition)

Year	Locomotive Diesel in Service (US)	Revenue Ton-Miles	Ton-Miles/Engine
1987	19,647	943,747	48.04
1988	19,364	996,182	51.45
1989	19,015	1,013,841	53.32
1990	18,835	1,033,969	54.90
1991	18,344	1,038,875	56.63
1992	18,004	1,066,781	59.25
1993	18,161	1,109,309	61.08
1994	18,496	1,200,701	64.92
1995	18,810	1,305,688	69.41
1996	19,267	1,355,975	70.38
1997	19,682	1,348,926	68.54
1998	20,259	1,376,802	67.96
1999	20,254	1,433,461	70.77
2000	20,026	1,465,960	73.20

As shown in Figure 2, there is a relatively good correlation between net ton-miles per engine growth and industrial production. Because net ton-miles per engine data are compiled by the railroad industry and pertains directly to the railroad segment, staff believes that net ton-miles per engine will better characterize future traffic level changes.

Figure 2. Ton-miles/Engine vs. Industrial Production (index base year = 1987)



The ton-miles/engine data were projected to calculate the future growth rate of traffic level using a linear equation.

Staff also made changes to the "Increased Rail Lube and Aerodynamics" assumption shown in Tables 3 and 4. Staff has replaced increased rail lube and aerodynamics with gains from fuel efficiency. Using statistics from the AAR factbook, revenue tons-miles per gallon of fuel consumed was used to approximate the fuel efficiency gains for 1987-2000. For 2000 and beyond, staff used the U.S. Department of Energy's report entitled "Railroad and Locomotive Technology Roadmap" to approximate the future fuel efficiency gains.

Tables 6, 7, and 8 present the revised growth factors to be used to project the baseline (1987) locomotive emissions inventory into the future.

Table 6. ARB Revised Growth 1987-2000

Train Operation Type	Fuel Efficiency	Introduction of New Locos	Changes in Traffic Levels	Cumulative Net Growth in Emissions	Annual Growth
Intermodal-foreign	-24.8%	-3.2%	110.0%	82.0%	4.71%
Intermodal-domestic	-24.8%	-3.2%	50.0%	22.0%	1.54%
Mixed & Bulk	-24.8%	-3.2%	50.0%	22.0%	1.54%
Local	-2.4%	0%	-2.0%	-4.4%	-0.35%
Yard	0.0%	0%	-25.0%	-25.0%	-2.19%
Passenger	-5.6%	0%	10.0%	6.3%	0.47%

The benefit of new locomotives with cleaner burning engines is accounted for in the control factor from U.S. EPA's regulation beginning in 2001, which takes into account introduction of new locomotive engines meeting Tier I and Tier II standards.

Table 7. ARB Revised Growth 2001-2010

Train Operation Type	Rail Lube	Train Control	Changes in Traffic Levels	Cumulative Net Growth in Emissions	Annual Growth
Intermodal-foreign	-4.8%	-4.8%	77.0%	67.5%	5.29%
Intermodal-domestic	-4.8%	-4.8%	22.5%	13.0%	1.23%
Mixed & Bulk	-4.8%	-4.8%	22.5%	13.0%	1.23%
Local	0.0%	0.0%	-10.0%	-10.0%	-1.05%
Yard	0.0%	0.0%	-15.0%	-15.0%	-1.61%
Passenger	0.0%	0.0%	15.0%	15.0%	1.41%

Table 8. ARB Revised Growth 2010-2020

Train Operation Type	Rail Lube	Train Control	Changes in Traffic Levels	Cumulative Net Growth	Annual Growth
Intermodal-foreign	-4.2%	-4.2%	67.0%	58.7%	4.73%
Intermodal-domestic	-4.2%	-4.2%	18.0%	9.7%	0.93%
Mixed & Bulk	-4.2%	-4.2%	18.0%	9.7%	0.93%
Local	0.0%	0.0%	0.0%	0.0%	0.00%
Yard	0.0%	0.0%	0.0%	0.0%	0.00%
Passenger	0.0%	0.0%	15.0%	15.0%	1.41%

Table 9. Revised Growth in Emissions (Base Year 1987)

Year	Intermodal-foreign	Intermodal-domestic	Mixed & Bulk	Local	Yard	Passenger
1987	1.00	1.00	1.00	1.00	1.00	1.00
1988	1.05	1.02	1.02	1.00	0.98	1.00
1989	1.10	1.03	1.03	0.99	0.96	1.01
1990	1.15	1.05	1.05	0.99	0.94	1.01
1991	1.20	1.06	1.06	0.99	0.92	1.01
1992	1.26	1.08	1.08	0.98	0.90	1.02
1993	1.32	1.10	1.10	0.98	0.88	1.02
1994	1.38	1.11	1.11	0.98	0.86	1.02
1995	1.45	1.13	1.13	0.97	0.84	1.03
1996	1.51	1.15	1.15	0.97	0.82	1.03
1997	1.59	1.17	1.17	0.97	0.80	1.03
1998	1.66	1.18	1.18	0.96	0.78	1.04
1999	1.74	1.20	1.20	0.96	0.77	1.04
2000	1.82	1.22	1.22	0.96	0.75	1.04
2001	1.92	1.24	1.24	0.95	0.74	1.06
2002	2.02	1.25	1.25	0.94	0.73	1.07
2003	2.12	1.27	1.27	0.93	0.71	1.09
2004	2.24	1.28	1.28	0.92	0.70	1.10
2005	2.36	1.30	1.30	0.91	0.69	1.12
2006	2.48	1.31	1.31	0.90	0.68	1.14
2007	2.61	1.33	1.33	0.89	0.67	1.15
2008	2.75	1.35	1.35	0.88	0.66	1.17
2009	2.90	1.36	1.36	0.87	0.65	1.18
2010	3.05	1.38	1.38	0.86	0.64	1.20
2011	3.19	1.39	1.39	0.86	0.64	1.22
2012	3.34	1.40	1.40	0.86	0.64	1.23
2013	3.50	1.42	1.42	0.86	0.64	1.25
2014	3.67	1.43	1.43	0.86	0.64	1.27
2015	3.84	1.44	1.44	0.86	0.64	1.29
2016	4.02	1.46	1.46	0.86	0.64	1.31
2017	4.21	1.47	1.47	0.86	0.64	1.32

2018	4.41	1.48	1.48	0.86	0.64	1.34
2019	4.62	1.50	1.50	0.86	0.64	1.36
2020	4.84	1.51	1.51	0.86	0.64	1.38

Control Factors for U.S. EPA regulation

In December 1997, the U.S. EPA finalized the locomotive emission standard regulation. The regulatory support document lists the control factors used (http://www.epa.gov/otaq/regs/nonroad/locomotv/frm/locorsd.pdf). Staff modified the control factors to incorporate the existing memorandum of understanding (http://www.arb.ca.gov/msprog/offroad/loco/loco.htm) between the South Coast AQMD and the railroads that operate in the region. Previously, one control factor was applied statewide. In the revised emissions inventory starting in 2010, a lower control factor reflecting the introduction of lower emitting locomotive engines in the SCAB region was applied. Tables 10 and 11 show the revised control factors. Road hauling definition as used by U.S. EPA applies to the line-haul/intermodal, mixed, and local/short haul train type in the emissions inventory.

Table 10. Revised Statewide Control Factors

Year	State Road Hauling HC	State Road Hauling NOx	State Road Hauling PM	State Switcher HC	State Switcher NOx	State Switcher PM	State Passenger HC	State Passenger NOx	State Passenger PM
1999	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2000	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2001	1.00	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2002	1.00	0.88	1.00	1.00	0.98	1.00	1.00	0.98	1.00
2003	1.00	0.82	1.00	1.00	0.97	1.00	1.00	0.96	1.00
2004	1.00	0.75	1.00	1.00	0.95	1.00	1.00	0.94	1.00
2005	0.96	0.68	0.96	0.99	0.93	0.99	0.98	0.92	0.98
2006	0.92	0.62	0.92	0.99	0.91	0.99	0.96	0.90	0.96
2007	0.89	0.59	0.89	0.98	0.89	0.98	0.94	0.83	0.94
2008	0.87	0.57	0.86	0.98	0.87	0.97	0.92	0.76	0.92
2009	0.84	0.55	0.84	0.97	0.85	0.97	0.91	0.69	0.90
2010	0.82	0.54	0.81	0.96	0.83	0.96	0.89	0.62	0.88
2011	0.81	0.53	0.80	0.96	0.81	0.95	0.87	0.57	0.87
2012	0.80	0.53	0.79	0.95	0.79	0.94	0.85	0.56	0.85
2013	0.79	0.52	0.78	0.94	0.77	0.93	0.83	0.54	0.83
2014	0.77	0.51	0.76	0.94	0.75	0.93	0.82	0.53	0.81
2015	0.76	0.50	0.75	0.93	0.73	0.92	0.80	0.52	0.79
2016	0.75	0.50	0.74	0.92	0.71	0.91	0.78	0.51	0.77
2017	0.74	0.49	0.72	0.91	0.70	0.90	0.76	0.50	0.75
2018	0.73	0.48	0.71	0.90	0.69	0.89	0.74	0.49	0.73
2019	0.71	0.48	0.70	0.89	0.68	0.88	0.73	0.48	0.71
2020+	0.70	0.47	0.69	0.89	0.67	0.87	0.71	0.47	0.69

Table 11. Revised SCAB Control Factors

Year	SCAB Road Hauling HC	SCAB Road Hauling NOx	SCAB Road Hauling PM	SCAB Switcher HC	SCAB Switcher NOx	SCAB Switcher PM
1999	1.00	1.00	1.00	1.00	1.00	1.00
2000	1.00	0.99	1.00	1.00	1.00	1.00
2001	1.00	0.95	1.00	1.00	1.00	1.00
2002	1.00	0.88	1.00	1.00	0.98	1.00
2003	1.00	0.82	1.00	1.00	0.97	1.00
2004	1.00	0.75	1.00	1.00	0.95	1.00
2005	0.96	0.68	0.96	0.99	0.93	0.99
2006	0.92	0.62	0.92	0.99	0.91	0.99
2007	0.89	0.59	0.89	0.98	0.89	0.98
2008	0.87	0.57	0.86	0.98	0.87	0.97
2009	0.84	0.55	0.84	0.97	0.85	0.97
2010	0.82	0.36	0.81	0.96	0.36	0.96
2011	0.81	0.36	0.80	0.96	0.36	0.95
2012	0.80	0.36	0.79	0.95	0.36	0.94
2013	0.79	0.36	0.78	0.94	0.36	0.93
2014	0.77	0.36	0.76	0.94	0.36	0.93
2015	0.76	0.36	0.75	0.93	0.36	0.92
2016	0.75	0.36	0.74	0.92	0.36	0.91
2017	0.74	0.36	0.72	0.91	0.36	0.90
2018	0.73	0.36	0.71	0.90	0.36	0.89
2019	0.71	0.36	0.70	0.89	0.36	0.88
2020+	0.70	0.36	0.69	0.89	0.36	0.87

Addition of Class III Locomotive and Industrial/Military Locomotive

The annual hours operated by the class III railroads are shown in Table 12. The results were tabulated from ARB Stationary Source Division's (SSD) survey (http://www.arb.ca.gov/regact/carblohc/carblohc.htm) conducted to support regulation with regards to ARB ultra-clean diesel fuel.

Table 12. Short-Haul and Switcher Annual Hours for Class III Railroads

Air Basin	Operations	Population	Annual Hours Operated
Mountain Counties	SW	2	10214
Mojave Desert	L	10	27440
North Coast	L	3	5700
North Central Coast	L	1	1332
	SW	3	3996
Northeast Plateau	L	5	9892
South Coast	SW	21	75379
South Central Coast	L	5	3200
San Diego	L	4	5000
San Francisco	L	8	31600
	SW	4	5059
San Joaquin Valley	L	29	68780
	SW	19	72248
Sacramento Valley	L	6	11400
Total		120	331240

L = local short-haul, SW = switcher

The short-haul and switcher emission rate are derived from BAH report. The report cites studies from testing done at U.S. EPA and Southwest Research Institute.

Table 13. Short-Haul and Switcher Emission Rate

Emission Rate	Short-Haul (g/bhp-hr)	Switcher (g/bhp-hr)
HC	0.38	0.44
CO	1.61	1.45
NOx	12.86	15.82
PM	0.26	0.28
SOx	0.89	0.90
Fuel Rate (lb/hr)	120.00	60.00

Table 14. Statewide Summary of Industrial Locomotives

Air Basin	Number of Locomotives	Avg. HP	Avg. Age
Mojave Desert	9	1,138	56
Others	11	587	54
San Francisco	11	525	54
San Joaquin Valley	38	1,176	54
South Coast	24	1,290	55
TOTALS	93	1,055	55

Table 15. Statewide Summary of Military Locomotives

Air Basin	Number of Locomotives	Avg. HP	Avg. Age
Mojave Desert	7	900	50
Northeast Plateau	2	1,850	50
Sacramento Valley	1	500	50
San Diego	7	835	50
San Francisco	4	1525	47.5
San Joaquin Valley	2	400	50
South Central Coast	1	500	50
TOTALS	24	930	49.6

The data from the survey provides a reasonable depiction of railroad activities in 2003. To forecast and backcast, an assumption was made to keep the data constant and have no growth. More research is needed to quantify the growth projections of smaller, local railroad activities.

<u>Update to Passenger Trains</u>

ARB's survey of intrastate locomotives included passenger agency trains that operated within the state. Staff attempted to reconcile the survey results by calculating the operation schedules posted by the operating agency to obtain hours of operation and mileage information. The results of the survey and calculated operating hours were comparable. Table 16 lists the calculated annual hours operated and miles traveled used to estimate emissions.

Table 16. Passenger Trains Annual Miles and Hours

Air Basin	Annual Miles Operated	Annual Hours Operated
South Coast	3,700,795	92,392
South Central Coast	151,864	4,020
San Diego	914,893	25,278
San Francisco	2,578,862	77,944
San Joaquin Valley	674,824	17,313
Sacramento Valley	635,384	20,058
Total	8,656,621	237,006

The passenger train emission rate is derived from testing done at SWRI on several passenger locomotives.

Table 17. Passenger Train Emission Rate

Emission Rate	Passenger Train (g/bhp-hr)
HC	0.50
CO	0.69
Nox	12.83
PM	0.36
Sox	0.90
Fuel Rate (lb/hr)	455.00

Fuel Correction Factors

<u>Aromatics</u>

Previous studies quantifying the effects of lowering aromatic content are listed in Table 18. These studies tested four-stroke heavy-duty diesel engines (HDD). Although staff would have preferred to analyze data from tests performed on various locomotive engines to determine the effects of lower aromatics, these HDD tests are the best available resources to determine the fuel corrections factors due to lower aromatics.

Table 18. Effect of Lowering Aromatic Volume on PM Emission

STUDY	**Sulfur (ppm)**	**Aromatics (Volume %)**	**PM Reduction (%)**
Chevron (1984)	2,800	31	Baseline
Chevron (1984)	500	31	23.8
Chevron (1984)	500	20	32.2
Chevron (1984)	500	15	36.0
Chevron (1984)	500	10	39.9
CRC-SWRI (1988)	500	31	Baseline
CRC-SWRI (1988)	500	20	9
CRC-SWRI (1988)	500	15	13
CRC-SWRI (1988)	500	10	17

Source : http://www.arb.ca.gov/fuels/diesel/diesel.htm

Using a linear regression of the data from the Table 18, the PM reduction from a change in aromatic content can be described as :

<u>4-Stroke Engine</u>
PM reduction = [(Difference in Aromatic Volume) * 0.785 + 0.05666]/100

For 2-Stroke engines, staff used test data from SWRI's report published in 2000 entitled "Diesel Fuel Effects on Locomotive Exhaust Emissions" to estimate indirectly the potential PM reduction for 2-Stroke engines due to lower aromatics. Table 19 lists the summary of the test results.

Table 19. SWRI 2000 Study Summary Results

Locomotive Engine	Aromatic Changes (Volume %)	PM Difference (g/bhp-hr)	PM % Difference
4 Stroke	28.35 to 21.84	0.080	37.6%
2 Stroke	28.35 to 21.84	0.056	14.1%

Staff assumes that PM emission reduction from 2-Stroke engine will have a factor of 0.38 (14.1%/37.6%) to the 4-Stroke engine PM emission reduction.

Currently, the baseline locomotive emissions inventory assumes an aromatic total volume percent of 31%. Table 21 describes the changes in PM emission due to changes in total volume percent of aromatics.

Table 20. Examples of PM Reductions Due to Changes in Aromatic Total Volume Percent

Aromatic Volume Percent		PM Reduction	PM Reduction	PM Reduction
From	To	2 Stroke	4 Stroke	Composite
31	28	0.9%	2.4%	1.3%
31	19	3.6%	9.5%	5.1%
31	10	6.3%	16.5%	8.9%

*composite is 75% 2 Stroke Engine and 25% 4 Stroke Engine

Table 21, Table 22, and Table 23 show the PM emission reduction for the different type of fuels used in the state.

Table 21. PM Emission Percent Change of Line-Haul Due to Aromatics, Statewide

Calendar Year	CARB Aromatic Volume (%)	EPA Aromatic Volume (%)	Off-road Aromatic Volume (%)	Weighted Aromatic Volume (%)	PM Emission Percent Change
1992	31	31	31	31.00	0.00
1993	10	31	31	31.00	0.00
1994	10	31	31	31.00	0.00
1995	10	31	31	31.00	0.00
1996	10	31	31	31.00	0.00
1997	10	31	31	31.00	0.00
1998-2001	10	31	31	30.18	-0.004
2002-2006	10	31	31	29.05	-0.009
2007+	10	31	31	29.05	-0.009

Table 22. Class I Line Haul Weighted Aromatic Volume Percent by Air Basin

Interstate Locomotive	Air Basin	1993-2001 Weighted Aromatic	2002+ Weighted Aromatic
		Volume Percent	Volume Percent
Class I Line Haul	SCC	31.0	31.0
	MC	31.0	26.6
	MD	30.0	29.8
	NEP	31.0	27.9
	SC	31.0	31.0
	SF	28.6	23.1
	SJV	29.1	29.4
	SS	31.0	31.0
	SV	31.0	27.4

Table 23. PM Emission Reduction from Intrastate Locomotives Due to Aromatics by Air Basin, 1993+

Intrastate Locomotive	Air Basin	CARB Aromatic	EPA Aromatic	Nonroad Aromatic	Weighted Aromatic	PM Emission Reduction
		Volume Percent	Volume Percent	Volume Percent	Volume Percent	Percent
Class I Local/Yard	SC	10	31	31	29.0	-0.9%
	SJV	10	31	31	25.2	-2.4%
	MD	10	31	31	31.0	0.0%
	BA	10	31	31	13.9	-7.2%
	SD	10	31	31	13.2	-7.5%
	SV	10	31	31	13.2	-7.5%
	SCC	10	31	31	13.2	-7.5%
Class III Local/Yard	SC	10	31	31	31.0	0.0%
	SJV	10	31	31	18.6	-5.2%
	MD	10	31	31	10.0	-8.8%
	BA	10	31	31	10.0	-8.8%
	SD	10	31	31	10.0	-8.8%
	SV	10	31	31	10.0	-8.8%
	SCC	10	31	31	10.0	-8.8%
	NEP	10	31	31	26.6	-1.9%
	MC	10	31	31	31.0	0.0%
	NC	10	31	31	10.0	-8.8%
	NCC	10	31	31	10.0	-8.8%
Industrial/Military	SC	10	31	31	24.0	-3.0%
	SJV	10	31	31	24.0	-3.0%
	MD	10	31	31	24.0	-3.0%
	BA	10	31	31	24.0	-3.0%
	NEP	10	31	31	24.0	-3.0%
	SD	10	31	31	24.0	-3.0%
	SV	10	31	31	24.0	-3.0%
	SCC	10	31	31	24.0	-3.0%
Passenger	SC	10	31	31	10.8	-8.5%
	SJV	10	31	31	10.0	-8.8%
	BA	10	31	31	10.0	-8.8%
	SD	10	31	31	10.0	-8.8%
	SV	10	31	31	10.0	-8.8%
	SCC	10	31	31	12.1	-8.0%

Source : Fuel Estimate from http://www.arb.ca.gov/regact/carblohc/carblohc.htm

Sulfur

Currently, the baseline locomotive emissions inventory assumes an average fuel sulfur content of 2700 ppm. Industry has provided information on the sulfur content of the fuel that is currently being used by intrastate locomotives. Together with industry data and prior locomotive tests, staff believes a fuel correction factor should be incorporated into the model.

Table 24 shows the test data collected by the ARB, U.S. EPA, and others, where locomotive engines were tested on different fuel sulfur levels.

Table 24. Locomotive Engine Test with Different Sulfur Levels

Locomotive Engine	Fuel Properties Sulfur Content	Percent Change PM	Percent Change NOX	Percent Change CO	Percent Change HC	Source
EMD 12-645E3B	100/3300ppm	-0.29	-0.06	0.17	0.07	Fritz, 1991
GE DASH9-40C	330/3150ppm	-0.43	-0.07	-0.05	-0.18	Fritz (1995, EPA/SWRI)
MK 5000C	330/3150ppm	-0.71	-0.03	-0.03	-0.07	Fritz (1995, EPA/SWRI)
EMD 16-710G3B, SD70MAC	330/3150ppm	-0.38	-0.08	-0.30	-0.01	Fritz (1995, EPA/SWRI)
EMD SD70MAC	50/330ppm	-0.03	-0.04	0.07	0.01	Fritz (ARB/AAR, 2000)
EMD SD70MAC	50/4760ppm	-0.16	-0.06	0.08	0.03	Fritz (ARB/AAR, 2000)
EMD SD70MAC	330/4760ppm	-0.13	-0.03	0.01	0.01	Fritz (ARB/AAR, 2000)
GE DASH9-44CW	50/330ppm	-0.03	-0.03	-0.01	-0.04	Fritz (ARB/AAR, 2000)
GE DASH9-44CW	50/4760ppm	-0.39	-0.07	-0.02	0.02	Fritz (ARB/AAR, 2000)
GE DASH9-44CW	330/4760ppm	-0.38	-0.04	-0.02	0.06	Fritz (ARB/AAR, 2000)
GE DASH9-44CW	50/3190ppm	-0.27	-0.05	-0.03	0.01	Fritz (ARB/AAR, 2000)
GE DASH9-44CW	330/3190ppm	-0.25	-0.02	-0.02	0.04	Fritz (ARB/AAR, 2000)
GE DASH9-44CW	3190/4760ppm	-0.17	-.02	0.00	0.02	Fritz (ARB/AAR, 2000)
Average		-0.28	-0.05	-0.01	0.00	

From the above table, staff concluded that HC and CO emissions are not affected by different sulfur levels in the fuel. From these tests, staff computed the changes in PM emissions associated with changes in sulfur level. Staff corrected the PM emissions to account for the aromatic differences because the test data were not tested at the same aromatic volume percent. Because the locomotive engine testing was performed at various fuel sulfur levels (some at 330 ppm vs. 3190 ppm and some at 50 ppm vs. 3190 ppm), staff cannot assume the average percent change in PM emission is characteristics over the whole range of sulfur levels. From previous studies that staff has analyzed, it is possible to generate estimates of the percent change at various sulfur levels and throttle positions. Locomotive engines have 8 throttle positions plus dynamic braking and idle. During idle, braking, and throttle positions 1 and 2, there are no significant differences in emissions attributable to sulfur level. For the GE 4-stroke engine, effect of sulfur on PM for throttle positions 3 to 8 can be defined by using the following equations:

Equations to correct for PM for GE (4-Stroke) engines

Notch 8 : PM (g/bhp-hr) = 0.00001308 * (sulfur level,ppm) + 0.0967
Notch 7 : PM (g/bhp-hr) = 0.00001102 * (sulfur level,ppm) + 0.0845
Notch 6 : PM (g/bhp-hr) = 0.00000654 * (sulfur level,ppm) + 0.1037
Notch 5 : PM (g/bhp-hr) = 0.00000548 * (sulfur level,ppm) + 0.1320
Notch 4 : PM (g/bhp-hr) = 0.00000663 * (sulfur level,ppm) + 0.1513
Notch 3 : PM (g/bhp-hr) = 0.00000979 * (sulfur level,ppm) + 0.1565

For the EMD 2-stroke engine, throttle positions 3 to 8 can be defined by using the following equations:

Equations to correct for PM for EMD (2-Stroke) engines

Notch 8 : PM (g/bhp-hr) = 0.0000123 * (sulfur level,ppm) + 0.3563
Notch 7 : PM (g/bhp-hr) = 0.0000096 * (sulfur level,ppm) + 0.2840
Notch 6 : PM (g/bhp-hr) = 0.0000134 * (sulfur level,ppm) + 0.2843
Notch 5 : PM (g/bhp-hr) = 0.0000150 * (sulfur level,ppm) + 0.2572
Notch 4 : PM (g/bhp-hr) = 0.0000125 * (sulfur level,ppm) + 0.2629
Notch 3 : PM (g/bhp-hr) = 0.0000065 * (sulfur level,ppm) + 0.2635

Table 25. Examples of PM Reductions Due to Changes in Sulfur Level

Sulfur Level (ppm)		PM Reduction	PM Reduction	PM Reduction
From	To	2 Stroke	4 Stroke	Composite
3100	1900	4.1%	8.4%	5.2%
3100	1300	6.1%	12.6%	7.7%
1300	330	3.5%	7.9%	4.6%
1300	140	4.2%	9.5%	5.5%
140	15	1.8%	4.0%	2.4%

*composite is 75% 2 Stroke Engine and 25% 4 Stroke Engine

Data provided by industry show that when operating in California, the three main types of diesel fuel used in locomotive engines consists of CARB diesel, U.S. EPA on-highway diesel fuel, and U.S. EPA off-road or high sulfur diesel fuel. Four-stroke engines and two-stroke engines show different characteristics with respect to sulfur content. From the BAH report, 4-stroke engines make up about 25%, and 2-stroke engines make up about 75% of the locomotive engine fleet. Combining industry data, 4-stroke/2-stroke engine percent change and fleet makeup, Table 26 shows the percent change in PM emissions by year for the line-haul segment of the fleet.

Table 26. PM Emission Percent Change of Line-Haul Due to Sulfur, Statewide

Calendar Year	CARB Sulfur Content	EPA On-Highway Sulfur Content	EPA Off-road Sulfur Content	Weighted Fuel Sulfur Content	4-Stroke Engines PM Percent Change	2-Stroke Engines PM Percent Change	Weighted PM Emission Percent Change
1992	3100	3100	3100	3100	0.03	0.01	0.015
1993	500	330	3100	2919	0.02	0.01	0.009
1994	150	330	3100	2740	0.01	0.00	0.003
1995	140	330	3100	2557	-0.01	0.00	-0.006
1996	140	330	3100	2377	-0.02	-0.01	-0.014
1997	140	330	3100	2196	-0.04	-0.02	-0.022
1998-2001	140	330	3100	1899	-0.06	-0.03	-0.035
2002-2006	140	330	3100	1312	-0.10	-0.05	-0.061
2007-2010	15	15	330	129	-0.19	-0.09	-0.113
2011+	15	15	15	15	-0.31	-0.10	-0.153

Table 27 and Table 28 provide further details of weighted fuel sulfur level by air basin. Weighted sulfur levels vary significantly from one air basin to another.

Table 27. Class I Line Haul Weighted Fuel Sulfur by Air Basin

Interstate Locomotive	Air Basin	1998 Weighted Sulfur	2002-2006 Weighted Sulfur	2007-2010 Weighted Sulfur	2011+ Weighted Sulfur
		ppm	ppm	ppm	ppm
Class I Line Haul	SCC	1023	467	31	15
	MC	2333	1149	113	15
	MD	2352	1767	180	15
	NEP	2560	1632	166	15
	SC	1985	1472	145	15
	SF	1711	899	88	15
	SJV	1600	868	78	15
	SS	2425	1328	129	15
	SV	2473	1456	147	15

Table 28. Intrastate Locomotives Weighted Fuel Sulfur by Air Basin

Intrastate Locomotive	Air Basin	1993 Weighted Sulfur	1994-2006 Weighted Sulfur	2007-2010 Weighted Sulfur	2011+ Weighted Sulfur
		ppm	ppm	ppm	ppm
Class I Local/Yard	SC	346	312	15	15
	SJV	377	278	15	15
	MD	330	330	15	15
	BA	468	175	15	15
	SD	475	169	15	15
	SV	475	169	15	15
	SCC	475	169	15	15
Class III Local/Yard	SC	388	388	21	15
	SJV	1016	804	80	15
	MD	500	140	15	15
	BA	500	140	15	15
	SD	500	140	15	15
	SV	500	140	15	15
	SCC	500	140	15	15
	NEP	2628	2553	264	15
	MC	1573	1573	152	15
	NC	500	140	15	15
	NCC	500	140	15	15
Industrial/Military	SC	1340	1220	120	15
	SJV	1340	1220	120	15
	MD	1340	1220	120	15
	BA	1340	1220	120	15
	NEP	1340	1220	120	15
	SD	1340	1220	120	15
	SV	1340	1220	120	15
	SCC	1340	1220	120	15
Passenger	SC	493	147	15	15
	SJV	500	140	15	15
	BA	500	140	15	15
	SD	500	140	15	15
	SV	500	140	15	15
	SCC	483	159	15	15

Appendices B, C, and D contain the fuel correction factors for PM, NOx, and SOx emissions by air basin.

Revised Locomotive Emission Inventory

Tables 29, 30, and 31 show the revised locomotive emission inventory for calendar years 2000, 2010 and 2020.

Table 29. 2000 Statewide Locomotive Emission Inventory, tons/day

TYPE	HC	CO	NOx	PM	SOx
Intermodal/Line-Haul	3.79	12.26	77.67	1.84	4.06
Local/Short-Run	1.01	3.33	21.92	0.41	0.22
Mixed/Bulk	3.75	12.11	79.63	1.89	4.06
Passenger/Amtrak	0.46	0.83	10.24	0.20	0.00
Yard/Switcher	0.55	1.46	10.43	0.20	0.09
Total	9.56	29.99	199.90	4.55	8.43

Table 30. 2010 Statewide Locomotive Emission Inventory, tons/day

TYPE	HC	CO	NOx	PM	SOx
Intermodal/Line-Haul	4.59	18.05	49.87	2.02	0.47
Local/Short-Run	0.78	3.03	11.51	0.30	0.01
Mixed/Bulk	3.49	13.68	40.78	1.60	0.35
Passenger/Amtrak	0.49	1.00	7.62	0.21	0.00
Yard/Switcher	0.45	1.21	6.57	0.16	0.01
Total	9.79	36.97	116.36	4.30	0.85

Table 31. 2020 Statewide Locomotive Emission Inventory, tons/day

TYPE	HC	CO	NOx	PM	SOx
Intermodal/Line-Haul	5.67	26.11	67.52	2.43	0.07
Local/Short-Run	0.68	3.03	10.63	0.26	0.01
Mixed/Bulk	3.27	15.02	41.40	1.46	0.04
Passenger/Amtrak	0.45	1.16	13.04	0.19	0.00
Yard/Switcher	0.42	1.21	6.04	0.15	0.01
Total	10.48	46.53	138.63	4.48	0.13

Appendix A

Methodology to Calculate Locomotive Inventory

Methodology

The methodology and assumptions used for estimating locomotive emissions consists of several steps taken from the Booz-Allen Hamilton's Locomotive Emission Study report (http://www.arb.ca.gov/app/library/libcc.php). First, emission factor data from various engine manufacturers such as EMD and General Electric (GE) must be gathered to calculate average emission factors for locomotives operated by the railroad companies. Second, train operations data, including throttle position profiles and time spent on various types of operations from different railroad companies needs to be estimated. Finally, the locomotive emission inventory can be calculated using train operations data, emission factors, and throttle position profiles.

Step 1 – Average Emission Factors

Engine emission factors are required for the different locomotive engines manufactured by the major locomotive suppliers EMD or GE. Emission factors are obtained from testing done by either the engine manufacturers or by Southwest Research Institute, a consulting company that has performed many tests on locomotive engines. Table A-1 lists the available emission factors.

Table A-1. Available Emission Factors for Different Locomotive Engines

Engine Manufacturer	Engine Model	Locomotive Model
EMD	12-567BC	SW10
EMD	12-645E	SW1500,MP15,GP15-1
EMD	16-567C	GP9
EMD	16-645E	GP38,GP38-2, GP28
EMD	12-645E3B	GP39-2
EMD	12-645E3	GP39-2, SD39
EMD	16-645E3	GP40, SD40, F40PH
EMD	16-645E3B	GP40-2, SD40-2, SDF40-2, F40PH
EMD	16-645F3	GP40X, GP50, SD45
EMD	16-645F3B	SD50
EMD	20-645E3	SD45,SD45-2, F45, FP45
EMD	16-710G3	GP60, SD60, SD60M
GE	127FDL2500	B23-7
GE	127FDL3000	SF30B
GE	167FDL3000	C30-7, SF30C
GE	167FDL4000	B40-8

Source: BAH report, 1992

Next, the locomotive roster from the largest railroad companies operating in the state were obtained. Table A-2 lists the locomotive roster for railroad companies in 1987.

Table A-2. Locomotive Roster 1987

					Type of Service		
Railroad Company	Engine Manufacturer	Engine Model	Horsepower Rating	Units	Line Haul	Local	Yard/Switcher
ATSF	EMD	16-567BC	1500	211			X
ATSF	EMD	16-567C	1750	53			X
ATSF	EMD	16-567D2	2000	71		X	X
ATSF	EMD	16-645E	2000	69		X	X
ATSF	EMD	12-645E3	2300	62		X	
ATSF	EMD	12-645E3B	2300	60		X	
ATSF	EMD	16-645E3	2500	231	X	X	
ATSF	EMD	16-645E3	3000	18	X	X	
ATSF	EMD	16-645E3B	3000	203	X	X	
ATSF	EMD	16-645F3	3500	52	X		
ATSF	EMD	16-645F3B	3600	15	X		
ATSF	EMD	20-645E3	3600	243	X		
ATSF	EMD	16-710G3	3800	20	X		
ATSF	GE	GE-12	2350	60		X	
ATSF	GE	GE-12	3000	10	X	X	
ATSF	GE	GE-16	3000	226	X	X	

ATSF	GE	GE-16	3600	43	X		
ATSF	GE	GE-16	3900	3	X		
ATSF	GE	GE-16	4000	20	X		
Union Pacific	EMD	16-645BC	1200	56			X
Union Pacific	EMD	12-567A	1200	12			X
Union Pacific	EMD	12-645E	1500	281			X
Union Pacific	EMD	16-567CE	1500	35			X
Union Pacific	EMD	16-645E	2000	365		X	X
Union Pacific	EMD	12-645E3C	2300	24		X	
Union Pacific	EMD	16-567D3A	2500	16		X	
Union Pacific	EMD	16-645E3	3000	828	X	X	
Union Pacific	EMD	16-645E3B	3000	446	X	X	
Union Pacific	EMD	16-645F3	3500	36	X		
Union Pacific	EMD	16-645F3B	3600	60	X		
Union Pacific	EMD	16-710G3	3800	227	X		
Union Pacific	GE	GE-12	2300	106		X	
Union Pacific	GE	GE-12	3000	57	X	X	
Union Pacific	GE	GE-16	3000	156	X	X	
Union Pacific	GE	GE-16	3750	60	X		
Union Pacific	GE	GE-16	3800	256	X		
Southern Pacific	EMD	12-567C	1200	11			X
Southern Pacific	EMD	12-645E	1500	286			X
Southern Pacific	EMD	16-567BC	1500	37			X
Southern Pacific	EMD	16-567C	1750	326		X	
Southern Pacific	EMD	16-567D2	2000	145		X	
Southern Pacific	EMD	16-645E	2000	84		X	
Southern Pacific	EMD	12-645E3	2300	12		X	
Southern Pacific	EMD	16-645E3	2500	137	X	X	
Southern Pacific	EMD	16-645E3	3000	92	X		
Southern Pacific	EMD	16-645E3B	3000	353	X		
Southern Pacific	EMD	16-645F3	3500	4	X		
Southern Pacific	EMD	20-645E3	3600	425	X		
Southern Pacific	EMD	16-710G3	3800	65	X		
Southern Pacific	GE	GE-12	2300	15		X	
Southern Pacific	GE	GE-12	3000	107	X		
Southern Pacific	GE	GE-16	3600	20	X		
Southern Pacific	GE	GE-16	3900	92	X		

Source : BAH report, 1992

Using the available emission factors (shown in Table A-3) and the locomotive rosters, the average emission factors for each class of service can be calculated as shown in Table A-4. Emission factors for models that were not available were assigned an emission factor based on horsepower rating and the number of cylinders from similar engine models.

Table A-3. Emission Factors (BAH report 1992, gram/hour)

ENGINE	NOTCH	HP	FUEL RATE (lb/hr)	HC	CO	NOX	PM	SOX
12-567BC	8	1209	480	2792	5317	15540	341	819
	7	1022	394	2427	1655	14384	257	681
	6	835	315	1965	746	11472	232	545
	5	660	248	1494	527	8597	150	431
	4	482	179	1205	468	5645	115	317
	3	331	126	954	476	3586	104	228
	2	155	63	689	442	1502	50	117
	1	52	30	534	392	773	16	69
	IDLE	13	23	529	382	578	27	48
	BRK	60	69	1296	853	1532	48	138
12-645E	8	1586	630	666	5710	24128	448	1285
	7	1372	529	521	2085	21891	345	1070
	6	1109	419	377	676	17797	308	854
	5	885	332	274	416	14135	201	673
	4	669	249	194	354	9788	159	508
	3	440	167	145	339	5712	138	339
	2	233	95	117	294	2780	76	194
	1	72	41	93	182	1236	23	83
	IDLE	15	26	99	181	987	31	55
	BRK	70	80	145	350	3415	56	250
12-645E3	8	2415	897	1087	6617	31273	638	2439
	7	2075	772	705	5456	26948	503	2095
	6	1429	563	429	1371	19100	414	1457
	5	1069	406	310	716	16640	245	1101
	4	729	283	233	401	12254	181	765
	3	497	198	179	348	8326	163	537
	2	291	123	140	297	4924	98	335
	1	94	53	114	231	2463	29	144
	IDLE	16	30	95	432	1366	35	82
	BRK	79	113	195	612	3855	79	307
12-645E3B	8	2451	872	546	915	27886	620	1305
	7	2103	749	427	922	23563	488	1120
	6	1517	549	367	718	17956	404	821
	5	1105	404	316	376	13145	244	605
	4	878	324	247	338	10705	207	486
	3	594	223	203	313	7859	184	333
	2	417	159	147	348	5270	127	238
	1	111	54	91	205	1900	30	82
	IDLE	11	28	103	349	891	33	42
	BRK	36	76	226	528	2020	53	113
16-567C	8	1820	735	1110	6279	30813	523	1256
	7	1528	600	879	1942	25663	391	1008
	6	1231	500	664	938	19133	368	793
	5	960	400	489	565	14126	242	607

	4	666	300	337	411	9274	192	414
	3	431	200	271	430	5370	165	286
	2	181	100	189	360	2147	80	138
	1	80	50	155	214	1125	28	52
	IDLE	12	30.54545	152	234	1010	36	45
	BRK	50	105.5556	329	598	1881	74	124
16-645E	8	2124	854	807	3973	34755	607	2252
	7	1810	710	651	1773	29605	463	1864
	6	1465	567	483	926	23232	417	1494
	5	1161	442	372	604	16974	267	1161
	4	871	331	261	479	12410	211	871
	3	589	226	189	430	8137	186	595
	2	333	137	150	429	4330	109	359
	1	98	55	121	240	1815	31	145
	IDLE	15	32	124	283	1247	38	85
	BRK	82	103	269	699	2803	72	283
16-645E3	8	3159	1177	1169	5908	36933	837	2528
	7	2661	994	878	5029	31188	648	2129
	6	1971	740	611	1912	25568	545	1597
	5	1461	556	424	760	20899	336	1198
	4	1034	404	321	435	15416	258	869
	3	686	275	247	329	10179	227	590
	2	395	167	201	292	6040	133	359
	1	105	64	156	267	2810	36	137
	IDLE	17	40	185	564	1635	47	86
	BRK	69	114	293	655	4104	80	285
16-645E3B	8	3070	1137	1105	5159	40409	808	4022
	7	2492	924	798	3290	32325	602	3265
	6	1821	688	565	1530	26085	506	2441
	5	1438	549	432	935	20655	332	1942
	4	1030	400	319	515	15123	256	1411
	3	721	286	259	375	10766	236	1009
	2	363	154	185	290	5925	123	544
	1	105	63	138	251	3211	35	222
	IDLE	17	37	137	445	1717	44	129
	BRK	138	126	234	517	4676	88	444
16-645F3	8	3681	1345	1136	4565	47274	956	3424
	7	3182	1150	944	3532	44162	749	2927
	6	2212	816	590	1659	32363	600	2079
	5	1635	615	460	621	26341	371	1570
	4	1131	445	326	430	19195	284	1131
	3	725	305	262	355	11892	252	775
	2	444	203	237	316	8324	162	515
	1	250	137	58	302	5833	76	347
	IDLE	15	66	228	617	3024	78	167
	BRK	74	94	285	534	4569	66	238
16-645F3B	8	3866	1281	1082	1817	57021	911	2667
	7	3454	1136	933	1520	54573	740	2383
	6	2766	919	664	1743	42575	676	1909
	5	1876	652	488	1932	24333	394	1351
	4	1353	480	352	1083	18769	307	1001

	3	1005	363	312	744	14066	300	754
	2	475	179	209	228	7823	143	371
	1	205	92	39	59	1104	51	191
	IDLE	9	22	76	99	999	26	45
	BRK	36	91	276	403	2847	63	190
16-710G3	8	4035	1328	1332	1574	41686	944	3228
	7	3496	1147	1049	1678	38661	747	2769
	6	2637	888	738	2531	27684	653	2162
	5	1817	635	509	1127	18466	384	1563
	4	1351	478	405	513	14657	305	1175
	3	975	351	302	312	11079	290	857
	2	430	167	172	129	6486	133	408
	1	198	88	113	103	3732	49	216
	IDLE	5	23	63	80	1064	27	56
	BRK	23	134	369	330	3810	93	330
20-645E3	8	3819	1432	1375	2597	47133	1018	3361
	7	3344	1227	1171	2174	45484	799	2910
	6	2299	865	736	2345	25708	637	2047
	5	1741	665	523	1115	20831	402	1568
	4	1219	468	378	524	16480	299	1109
	3	781	310	315	453	10824	256	735
	2	435	187	230	452	5750	149	439
	1	111	68	164	316	2749	38	160
	IDLE	17	47	242	1017	1541	55	111
	BRK	95	157	327	850	4425	109	368
GE-16-3600	8	3700	1254	866	4844	38158	595	1877
	7	3100	1014	758	6069	31670	519	1517
	6	2450	858	489	8059	27127	505	1285
	5	1845	662	399	4335	20423	355	991
	4	1260	466	338	2738	12982	231	697
	3	850	298	246	1084	5970	154	447
	2	370	153	182	569	2742	80	228
	1	170	76	163	336	1159	70	113
	IDLE	27	28	333	534	320	38	41
	BRK	170	150	1384	2914	1461	451	228
GE-16-3000	8	3108	1090	753	4212	33181	517	1632
	7	2604	882	659	5278	27539	452	1319
	6	2058	746	425	7008	23588	439	1117
	5	1550	576	347	3770	17759	309	861
	4	1058	405	293	2381	11289	201	606
	3	714	259	214	942	5192	134	388
	2	311	133	158	495	2385	70	199
	1	143	66	142	292	1008	61	99
	IDLE	20	24	290	464	278	33	36
	BRK	128	130	1204	2534	1270	392	198
GE-12-3000	8	3000	991	684	3830	30165	470	1484
	7	2405	802	599	4798	25036	411	1199
	6	1996	679	386	6371	21444	399	1015
	5	1507	523	315	3427	16145	281	783
	4	1028	368	267	2164	10263	183	551
	3	642	236	194	857	4720	122	353

	2	319	121	144	450	2168	63	181
	1	137	60	129	266	917	55	90
	IDLE	15	18	218	349	209	25	27
	BRK	96	98	905	1905	955	295	149
GE-12-2500	8	2500	862	595	3330	26230	409	1290
	7	2004	697	521	4172	21770	357	1043
	6	1663	590	336	5540	18647	347	883
	5	1256	455	274	2980	14039	244	681
	4	857	320	232	1882	8924	159	479
	3	535	205	169	745	4104	106	307
	2	266	105	125	391	1885	55	157
	1	114	52	112	231	797	48	78
	IDLE	15	18	218	349	209	25	27
	BRK	96	98	905	1905	955	295	149

Table A-4. Average Emission Factor

Operation	HC (g/bhp-hr)	CO (g/bhp-hr)	NOX (g/bhp-hr)	PM (g/bhp-hr)	SOX (g/bhp-hr)
Line Haul	0.38	1.40	12.86	0.26	0.91
Local/Short	0.38	1.49	13.27	0.26	0.96
Yard/Switcher	0.51	1.49	15.77	0.28	0.88

Step 2 – Throttle Position Profiles and Train Operations Data

The railroad companies provided throttle position profiles. Locomotive engines operate at eight different constant loads and speeds called throttle notches. In addition, several other settings (idle and dynamic brake) are also common. For line haul and local operations, profiles were obtained from Train Performance Calculation (TPC) data and actual event recorder data, which are summarized in the BAH report.

For line haul operations, the data was modified to account for additional idle time between dispatch. Data supplied by Atchison, Topeka and Santa Fe (ATSF) indicates that the turnaround time for line haul locomotives in yards is approximately eight hours.

For local operations, several assumptions were used to develop throttle profiles. First, ten hours was used as an average hours per assignment. Second, the additional average idle time per day per locomotive was assumed to be ten hours.

The switch engine duty cycle is based upon actual tape data supplied by the ATSF railroad company on a switch engine that operated over a 2-day period. Yard engines are assumed to operate 350 days per year, with 2 weeks off for inspections and maintenance.

Train operations data provided by the railroad companies included :

Line Haul	Local	Yard/Switcher
Train type	Average trailing tons	Number of units assigned
Number of runs per year	Number of runs per year	Number of assignments
Average horsepower	Average horsepower	Average horsepower
Average units	Average units	
Origin/destination	Origin/destination	
Link miles		

Step 3 – Calculate Locomotive Emission Inventory

Emission inventories are calculated on a train-by-train basis using train operations data, average emission factor, and throttle position profiles.

Emission Inventory = Emission factor x average horsepower x time in notch per train x number of runs per year

Appendix B

PM Fuel Correction Factor by Air Basin

Interstate Locomotive	Air Basin	PM Fuel Correction Factor															
		pre 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-2010	2011+
Class I Line Haul	SCC	1.000	0.991	0.982	0.973	0.964	0.955	0.937	0.931	0.925	0.919	0.913	0.913	0.913	0.913	0.913	0.883	0.874
	MC	1.000	0.998	0.996	0.994	0.992	0.990	0.987	0.971	0.955	0.939	0.923	0.923	0.923	0.923	0.923	0.867	0.855
	MD	1.000	0.998	0.995	0.993	0.991	0.988	0.984	0.978	0.973	0.967	0.962	0.962	0.962	0.962	0.962	0.884	0.869
	NEP	1.000	0.999	0.998	0.998	0.997	0.996	0.995	0.983	0.971	0.959	0.947	0.947	0.947	0.947	0.947	0.875	0.860
	SC	1.000	0.996	0.993	0.989	0.986	0.982	0.975	0.970	0.965	0.960	0.955	0.955	0.955	0.955	0.955	0.888	0.874
	SF	1.000	0.993	0.987	0.980	0.974	0.967	0.954	0.940	0.926	0.912	0.898	0.898	0.898	0.898	0.898	0.851	0.840
	SJV	1.000	0.993	0.986	0.979	0.972	0.965	0.952	0.944	0.937	0.930	0.923	0.923	0.923	0.923	0.923	0.878	0.867
	SS	1.000	0.999	0.997	0.996	0.995	0.993	0.991	0.980	0.970	0.959	0.949	0.949	0.949	0.949	0.949	0.887	0.874
	SV	1.000	0.993	0.986	0.979	0.972	0.965	0.952	0.948	0.945	0.942	0.939	0.939	0.939	0.939	0.939	0.873	0.859

Intrastate Locomotive	Air Basin	PM Fuel Correction Factor															
		pre 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-2010	2011+
Class I Local/Switcher	SC	1.000	0.890	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.865	0.857
	SJV	1.000	0.863	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.836	0.828
	MD	1.000	0.906	0.906	0.906	0.906	0.906	0.906	0.906	0.906	0.906	0.906	0.906	0.906	0.906	0.906	0.882	0.874
	BA	1.000	0.778	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.747	0.739
	SD	1.000	0.772	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.741	0.733
	SV	1.000	0.772	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.741	0.733
	SCC	1.000	0.772	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.741	0.733
Class III Local/Switcher	SC	1.000	0.909	0.909	0.909	0.909	0.909	0.909	0.909	0.909	0.909	0.909	0.909	0.909	0.909	0.909	0.882	0.874
	SJV	1.000	0.839	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.787	0.776
	MD	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	BA	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	SD	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	SV	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	SCC	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	NEP	1.000	0.963	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.858	0.839
	MC	1.000	0.959	0.959	0.959	0.959	0.959	0.959	0.959	0.959	0.959	0.959	0.959	0.959	0.959	0.959	0.888	0.874
	NC	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	NCC	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.722	0.709
Industrial/Military	SC	1.000	0.894	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.831	0.818
	SJV	1.000	0.894	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.831	0.818
	MD	1.000	0.894	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.831	0.818
	BA	1.000	0.894	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.831	0.818
	NEP	1.000	0.894	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.831	0.818
	SD	1.000	0.894	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.831	0.818
	SV	1.000	0.894	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.831	0.818
	SCC	1.000	0.894	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.831	0.818
Passenger	SC	1.000	0.754	0.739	0.739	0.739	0.739	0.739	0.739	0.739	0.739	0.739	0.739	0.739	0.739	0.739	0.723	0.715
	SJV	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	BA	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	SD	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	SV	1.000	0.749	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.717	0.709
	SCC	1.000	0.764	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.733	0.725

Appendix C
NOx Fuel Correction Factor by Air Basin

Interstate Loc	Air Basin	NOx Fuel Correction Factor															
		pre 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007+
Class I Line H	SCC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	MC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	MD	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	NEP	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SF	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SJV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SS	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940

Intrastate Loc	Air Basin	NOx Fuel Correction Factor															
		pre 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007+
Class I Local/	SC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SJV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	MD	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	BA	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SD	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SCC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
Class III Loca	SC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SJV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	MD	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	BA	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SD	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SCC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	NEP	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	MC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	NC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	NCC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
Industrial/Milit	SC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SJV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	MD	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	BA	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	NEP	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SD	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SCC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
Passenger	SC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SJV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	BA	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SD	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SV	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
	SCC	1.000	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940

Appendix D
SOx Fuel Correction Factor by Air Basin

Interstate Locomotive	Air Basin	SOx Fuel Correction Factor																
		pre 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-2010	2011+
Class I Line Haul	SCC	1.000	0.896	0.793	0.689	0.586	0.482	0.379	0.327	0.276	0.225	0.173	0.173	0.173	0.173	0.173	0.011	0.006
	MC	1.000	0.977	0.955	0.932	0.909	0.887	0.864	0.755	0.645	0.535	0.426	0.426	0.426	0.426	0.426	0.042	0.006
	MD	1.000	0.979	0.957	0.936	0.914	0.893	0.871	0.817	0.763	0.709	0.654	0.654	0.654	0.654	0.654	0.067	0.006
	NEP	1.000	0.991	0.983	0.974	0.965	0.957	0.948	0.862	0.776	0.690	0.605	0.605	0.605	0.605	0.605	0.062	0.006
	SC	1.000	0.956	0.912	0.868	0.823	0.779	0.735	0.688	0.640	0.593	0.545	0.545	0.545	0.545	0.545	0.054	0.006
	SF	1.000	0.939	0.878	0.817	0.756	0.695	0.634	0.559	0.483	0.408	0.333	0.333	0.333	0.333	0.333	0.033	0.006
	SJV	1.000	0.932	0.864	0.796	0.728	0.660	0.593	0.525	0.457	0.389	0.322	0.322	0.322	0.322	0.322	0.029	0.006
	SS	1.000	0.983	0.966	0.949	0.932	0.915	0.898	0.797	0.695	0.594	0.492	0.492	0.492	0.492	0.492	0.048	0.006
	SV	1.000	0.986	0.972	0.958	0.944	0.930	0.916	0.822	0.728	0.634	0.539	0.539	0.539	0.539	0.539	0.054	0.006

Intrastate Locomotive	Air Basin	SOx Fuel Correction Factor																
		pre 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-2010	2011+
Class I Local/Switcher	SC	1.000	0.128	0.127	0.126	0.125	0.124	0.122	0.121	0.120	0.119	0.118	0.117	0.115	0.115	0.115	0.006	0.006
	SJV	1.000	0.139	0.136	0.133	0.130	0.126	0.123	0.120	0.116	0.113	0.110	0.106	0.103	0.103	0.103	0.006	0.006
	MD	1.000	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.006	0.006
	BA	1.000	0.173	0.164	0.154	0.144	0.134	0.124	0.114	0.104	0.095	0.085	0.075	0.065	0.065	0.065	0.006	0.006
	SD	1.000	0.176	0.165	0.155	0.145	0.135	0.124	0.114	0.104	0.093	0.083	0.073	0.062	0.062	0.062	0.006	0.006
	SV	1.000	0.176	0.165	0.155	0.145	0.135	0.124	0.114	0.104	0.093	0.083	0.073	0.062	0.062	0.062	0.006	0.006
	SCC	1.000	0.176	0.165	0.155	0.145	0.135	0.124	0.114	0.104	0.093	0.083	0.073	0.062	0.062	0.062	0.006	0.006
Class III Local/Switcher	SC	1.000	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.008	0.006
	SJV	1.000	0.376	0.369	0.362	0.355	0.348	0.341	0.333	0.326	0.319	0.312	0.305	0.298	0.298	0.298	0.029	0.006
	MD	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	BA	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	SD	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	SV	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	SCC	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	NEP	1.000	0.973	0.971	0.968	0.966	0.963	0.961	0.958	0.956	0.953	0.951	0.948	0.946	0.946	0.946	0.098	0.006
	MC	1.000	0.583	0.583	0.583	0.583	0.583	0.583	0.583	0.583	0.583	0.583	0.583	0.583	0.583	0.583	0.056	0.006
	NC	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	NCC	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
Industrial/Military	SC	1.000	0.496	0.492	0.488	0.484	0.480	0.476	0.472	0.468	0.464	0.460	0.456	0.452	0.452	0.452	0.044	0.006
	SJV	1.000	0.496	0.492	0.488	0.484	0.480	0.476	0.472	0.468	0.464	0.460	0.456	0.452	0.452	0.452	0.044	0.006
	MD	1.000	0.496	0.492	0.488	0.484	0.480	0.476	0.472	0.468	0.464	0.460	0.456	0.452	0.452	0.452	0.044	0.006
	BA	1.000	0.496	0.492	0.488	0.484	0.480	0.476	0.472	0.468	0.464	0.460	0.456	0.452	0.452	0.452	0.044	0.006
	NEP	1.000	0.496	0.492	0.488	0.484	0.480	0.476	0.472	0.468	0.464	0.460	0.456	0.452	0.452	0.452	0.044	0.006
	SD	1.000	0.496	0.492	0.488	0.484	0.480	0.476	0.472	0.468	0.464	0.460	0.456	0.452	0.452	0.452	0.044	0.006
	SV	1.000	0.496	0.492	0.488	0.484	0.480	0.476	0.472	0.468	0.464	0.460	0.456	0.452	0.452	0.452	0.044	0.006
	SCC	1.000	0.496	0.492	0.488	0.484	0.480	0.476	0.472	0.468	0.464	0.460	0.456	0.452	0.452	0.452	0.044	0.006
Passenger	SC	1.000	0.183	0.171	0.159	0.148	0.136	0.124	0.113	0.101	0.090	0.078	0.066	0.055	0.055	0.055	0.006	0.006
	SJV	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	BA	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	SD	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	SV	1.000	0.185	0.173	0.161	0.149	0.137	0.125	0.112	0.100	0.088	0.076	0.064	0.052	0.052	0.052	0.006	0.006
	SCC	1.000	0.179	0.168	0.157	0.146	0.135	0.124	0.113	0.103	0.092	0.081	0.070	0.059	0.059	0.059	0.006	0.006